Operations and Logistics

Joel Knapp

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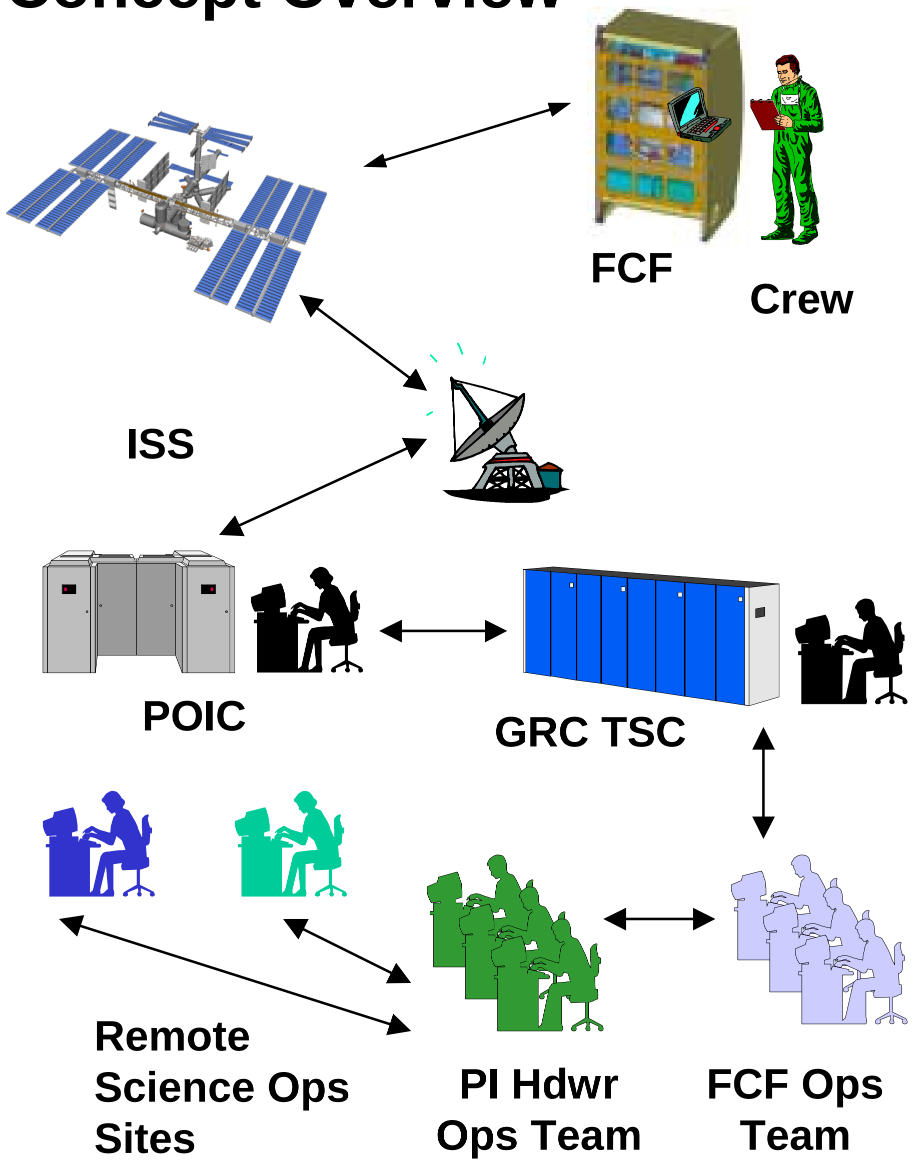
FCF Operations Concept Overview

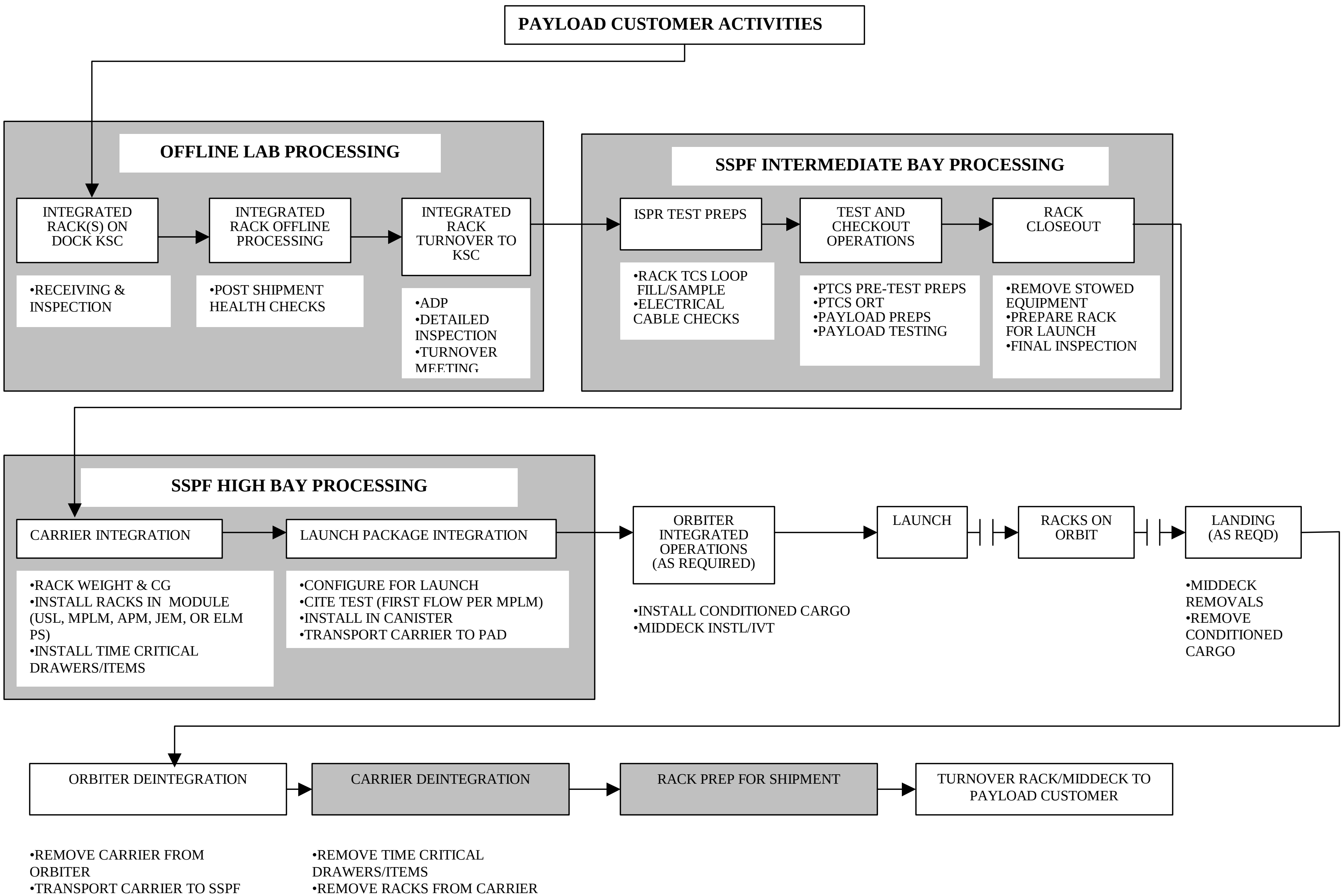
- The FCF is being designed for autonomous, ground-tended operations.
- FCF will undergo processing at GRC prior to shipment to the cape.
- Typically, once an experiment is set up by the crew, it will be operated from the ground.
- Experiment progress will be monitored by the Ops teams and the Ops teams will routinely uplink commands based on the experiment protocol.
- The FCF is being designed for quick and easy setup and reconfiguration.
- The FCF primary ground operations site is the GRC Telescience Support Center.



Ground Processing

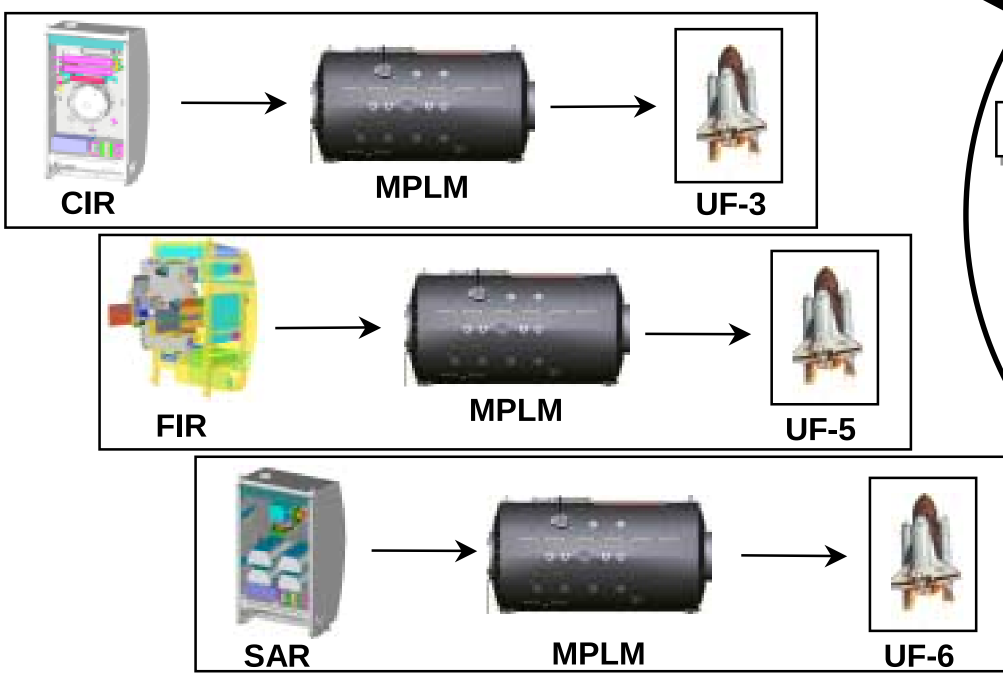
- Racks will be checked out at GRC in the PRCU.
- MDCA and LMM flight hardware will undergo FIVT in the FCF flight articles.
- Payload hardware will be turned over to FCF for shipment to KSC.
- Once at the Cape, FCF hardware will follow the Facility Rack processing flow.
- Sub Rack Payload processing at the Cape has not been defined yet.
- Specific requirements will be developed in the FCF processing and integration plans and documented in the appropriate data sets.

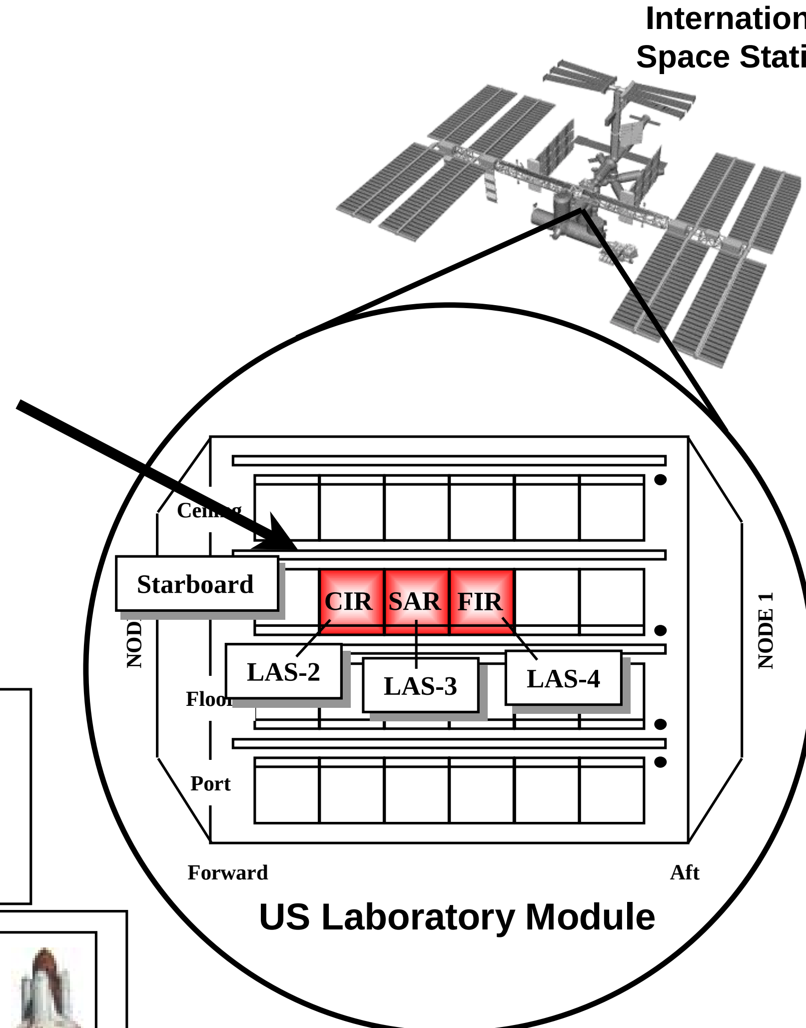
Facility Rack Processing



FCF Transportation to Orbit and Location in ISS

- The FCF CIR, FIR and SAR are transported to ISS in the MPLM.
- The FCF will be located in three contiguous rack locations in the US Lab (starboard side).

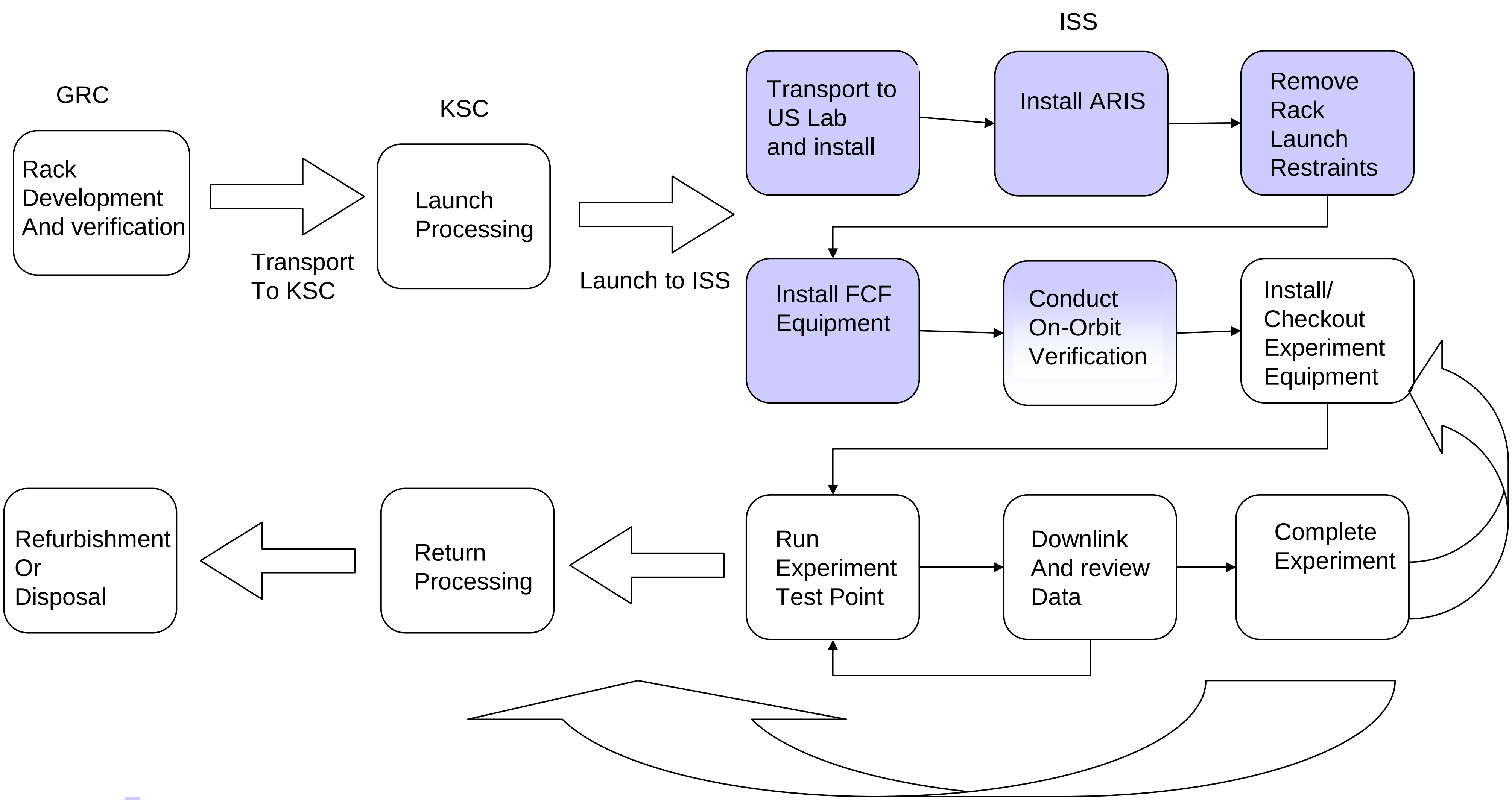




Rack locations LAS-2, LAS-3 and LAS-4 provide the required power, thermal, venting and data interfaces for the FCF.

FCF On-Orbit Ops

Generic FCF Rack Operations Concept Flow



Initial Rack Launch Only

FCF Operations Overview

Operations Concept Overview

- FCF On-Orbit Assembly
- CIR On Orbit checkout
- MDCA Setup
- MDCA Experiment Synopsis
- MDCA resource Estimates
- FIR On Orbit checkout
- LMM Setup
- CVB Synopsis
- CVB Resource Estimates

FCF On-Orbit Assembly and Configuration: ARIS Installation

- Upon Placement of the CIR/ISPR into its Installation Location, and placing on Pivot Fittings at Installation Standoff
- Major Steps
  - Install Upper Actuator Pair
  - Install Upper Snubber Adjustment Fittings
  - Install Isolation Plate Hardware
  - Pivot Rack into Operation Position
  - Adjust Upper Snubber Mechanisms
  - Tilt Down ISPR
  - Secure ISPR;
  - Prepare Isolation Mechanisms for ARIS Operation
  - Pivot ISPR to Operation Position
  - Engage Isolation Mechanisms
  - Connect utilities to ISPR
  - Complete configuration and assembly
- Total Estimated Crew Time for On-orbit Assembly and Installation of ARIS= 420 minutes (6 hours)

On-Orbit Configuration of the FCF Racks: FCF Launch Restraint Hardware

- After the ARIS installation activities are complete the FCF Launch Restraint hardware must be removed
- This needs to be done for each FCF rack
- Major Steps
  - Remove the 4 Boeing access panels on the ISPR
  - Remove the ATCU Launch screws and spacers
  - Remove the optics bench launch screws
  - Replace the access panels
  - Remove Door launch restraints
  - Remove Door clips
  - Open Doors and remove GC instrumentation package>>>
  - Close Doors
  - Install rack to station umbilicals
- Total Crew time required to complete = 3 hours

Setup for On-Orbit Calibration

- Install CIR Equipment:
  - FOMA Control Unit
  - CIR Provided Diagnostics
  - Verification Chamber insert and gas bottles
- Total Crew Time = 3.5 Hours
- Crew Time (Total) Needed for Verification Routines: 0 Hours
- **Total Crew Time Needed for On-orbit CIR verification: 3.5 Hours**

Conduct On-Orbit Verification

4 types of on orbit verification

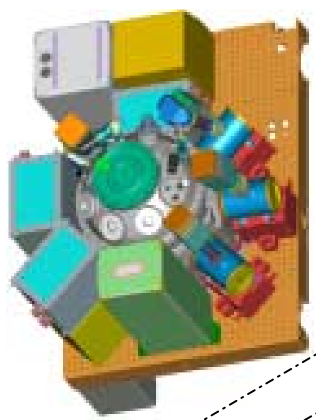
- Initial verification when arrive on orbit
  - This verification will check out most rack functions
  - Communications
  - FCF performance
- Calibration/safety verifications
  - On Orbit Leak Integrity Check (OLIC)
  - Pressure Transducers
  - Calibration CIA incorporating pressure and temperature sources calibrated to NIST standard
  - Optical targets required for diagnostic verification
- **No Crew time required**

Reconfigure for Science

- Remove CIR provided Equipment
  - Diagnostics Packages
  - Chamber Insert
  - Gas Bottles
- Install Experiment provided equipment
  - Avionics Package
  - Chamber Insert
  - Gas bottles
  - Diagnostics Packages

CIR/MDCA Experiment Operational Flow

Configuration
- Remove CIR verification equipment
- Install Experiment Avionics Package
- Install Experiment Diagnostics
- Configure/Install CIA
- Install Gas Bottles



Post Run
- Post Process Data
- Transfer Data to IOP
- Power down to Minimal Power Mode
- Downlink Data (Uplink Procedures)
- Power Down

Pre-Test Operations
- Apply Power
- Perform CIR self-test
- Experiment check-out

Test Operations
- Fill Chamber
- Power on Diagnostics
- Review Health and Status
- Start Test Run – Perform Real-Time Test Procedures
- Downlink Real-Time Data
- Shut-down Diagnostics

DCE-2: Estimated Crew Time for DCE-2 Configuration

(Assuming Empty UMLs and Bottle Locations)*

TASK	CREW TIME (min)	CREW TIME ELAPSED (min)	CREW TIME ELAPSED (hrs)
Fold Open Doors and Secure	10	10	0.17
Translate and Rotate Optics Bench	20	30	0.50
Unstow Avionics Box (SAP)	15	45	0.75
Install Avionics Box (SAP) into UML #9	10	55	0.92
Unstow Removable Latch (RL) & Secure-(1min)	9	64	1.07
Unstow CIR IPP	15	79	1.32
Install CIR IPP into UML 5	20	99	1.65
Unstow Illumination Package	15	114	1.90
Attach RL to Illumination Package	2	116	1.93
Install Illumination Package into UML 6	5	121	2.02
Unstow IPSU	15	136	2.27
Detach LM from Illumination Package	2	138	2.30
Attach RL to IPSU	2	140	2.33
Install IPSU into UML 7	5	145	2.42
Unstow CIR LLL-UV (OH)	15	160	2.67
Detach RL from IPSU	2	162	2.70
Attach RL to CIR LLL-UV (OH)	2	164	2.73
Install CIR LLL-UV (OH) into UML 8	5	169	2.82
Unstow IPSU	15	184	3.07
Detach RL from CIR LLL-UV (OH)	2	186	3.10

Notes:

* Current Estimates for MDCA as of 01/30/2001

Assumptions Included In DCE-2 Configuration and Test Execution

- Crew time for restraining or tie down is included in times given for crew actions
- Experiment Runs are operated entirely by Ground Operation
- Crew is trained and practiced in the use of hardware.

DCE-2: Estimated Crew Time for DCE-2 Configuration – Continued

TASK	CREW TIME (min)	CREW TIME ELAPSED (min)	CREW TIME ELAPSED (hrs)
Attach RL to IPSU	2	187	3.12
Install IPSU into UML 1	5	192	3.20
Unstow CIR HFR/HR	15	207	3.45
Detach RL from IPSU	2	209	3.48
Attach RL to CIR HFR/HR	2	211	3.52
Install CIR HFR/HR into UML 2	5	216	3.60
Unstow IPSU	15	231	3.85
Detach RL from CIR HFR/HR	2	233	3.88
Attach RL to IPSU	2	235	3.92
Install IPSU into UML 3	5	240	4.00
Unstow CIR LLL-IR (CH)	15	255	4.25
Detach RL from IPSU	2	257	4.28
Attach RL to CIR LLL-IR (CH)	2	259	4.32
Install CIR LLL-IR (CH) into UML 4	5	264	4.40
Detach RL	2	266	4.43
Fold Up and Translate Optics Bench	20	286	4.77
Open Chamber Door and Secure	5	291	4.85
Unsecure RL and Stow RL	10	301	5.02
Unstow CIA	15	316	5.27

DCE-2: Estimated Crew Time for DCE-2 Configuration – Continued

Total Estimated Crew Time Needed to Configure Combustion Integrated Rack so that the Execution of DCE-2 May Begin

TASK	CREW TIME (min)	CREW TIME ELAPSED (min)	CREW TIME ELAPSED (hrs)
Install both Fuel Resevoirs onto front of CIA	20	363	6.05
Push in CIA & Lock into fully Installed Pos.	2	365	6.08
Connect 2 cooling loops to CIA IRR	2	367	6.12
Connect Electric Connects to IRR	2	369	6.15
Close Chamber Door and Lock	5	374	6.23
Unstow 1 Adsorber Cartridge	15	389	6.48
Install 1 Adsorber Cartridge (15 min/bottle)	10	399	6.65
Unstow 1 2.25Liter Bottle of O2	15	414	6.90
Install 1 2.25Liter Bottle O2	2	416	6.93
Unstow 1 1Liter Bottle He	15	431	7.18
Install 1 1Liter Bottles He (2 min/bottle)	2	433	7.22
Close Rack Doors and Secure	10	443	7.38
TOTAL (Minutes) to configure for DCE-2	**443**	**443**	**443**
TOTAL (Hours) to configure for DCE-2	**7.38**	**7.38**	**7.38**

Example of Typical Day for Test Execution of DCE-2

***Actual number of Test Runs Per Day or Sequence will vary according to PI's needs**

Crew Unlock ARIS Securing Pins (4 Total)	10	0	0
Power Up (EPCU, IOP, ECU, ARIS, FOMA, Diagnostics)	0	30	30
Image Checkout	0	10	40
Fill Empty Chamber	0	90	130
Run#1: Deploy Droplet, Ignite, Data Capture	0	4	134
Run#2: Deploy Droplet, Ignite, Data Capture	0	4	138
Run#3: Deploy Droplet, Ignite, Data Capture	0	4	142
Run#4: Deploy Droplet, Ignite, Data Capture	0	4	146
Data to IOP	0	30	176
Downlink Data	0	339	515
Filter Chamber Gas Through Adsorber Cartridge	0	0	515
Run#5: Deploy Droplet, Ignite, Data Capture	0	4	519
Run#6: Deploy Droplet, Ignite, Data Capture	0	4	523
Run#7: Deploy Droplet, Ignite, Data Capture	0	4	527
Partial Chamber Vent and Fill	0	10	537
Run#8: Deploy Droplet, Ignite, Data Capture	0	4	541
Data to IOP	0	30	571
Downlink Data	0	339	910
Power Down (EPCU, IOP, ECU, ARIS, FOMA, Diagnostics)	0	1	911
Crew Lock ARIS Securing Pins (4 Total)	10	0	911
Total Minutes (During one day of runs)	**20**	**911**	**911**
Total Hours (During one day of runs)	**0.33**	**15.18**	**15.18**

Estimated Total Crew Time Needed for the Execution of DCE-2 over its Lifespan

Estimated Crew Time During Experiment			
Task		**TIME (min)**	**TIME (hrs)**
11 Syringes: 5 changes @ 30 min. each		150	2.5
Bottle Changeout: Remove 1 Add 1 (3 times total)		90	1.50
Opening and Closing Doors (7 times total) @ 20 min. each		140	2.33
Daily ARIS Securing and Unsecuring (46 days @ 20 min)		920	15.33
Total Estimated Crew Time During Experiment		1300	21.67
NOTE: This Table does not account for overlapping actions			
NOTE2:This Table entails the total amount of time to be distributed amongst the remaining runs.			
Assumptions: 8 Runs per day; 364 total runs for DCE-2			

Post DCE-2 Crew Time for Reconfiguration of CIR for BCDCE

TASK	CREW TIME (minutes)	CREW TIME ELAPSED (min)	CREW TIME ELAPSED (hrs)
Fold Open Doors and Secure	10	10	0.17
Uninstall 1 used Adsorber Cartridge	15	25	0.42
Stow used Adsorber Cartridge	10	35	0.58
Unistall 1 used 2.25L O2 Bottle	2	37	0.62
Stow used 2.25L O2 Bottle	10	47	0.78
Open and Secure Chamber Door	5	52	0.87
Disconnect electrical connectors from the CIA & IRR	2	54	0.90
Disconnect cooling loops from CIA & IRR then secure	3	57	0.95
Unlock CIA then remove from combustion chamber	24	81	1.35
Move CIA to Work Maintenance Bench and secure	5	86	1.43
Uninstall 2 used Fuel Resevoirs from CIA	20	106	1.77
Stow the 2 used Fuel Resevoiers	8	114	1.90
Unstow 2 new Fuel Reservoirs	8	122	2.03
Install 2 new Fuel Reseroirs onto CIA	20	142	2.37

Post DCE-2 Crew Time for Reconfiguration of CIR for BCDCE – Continued

TASK	CREW TIME (minutes)	CREW TIME ELAPSED (min)	CREW TIME ELAPSED (hrs)
Remove 2 shroud plates and secure	6	147	2.45
Remove 2 used needle assemblies	5	152	2.53
Stow 2 used needle assemblies	10	162	2.70
Unstow 2 new needle assemblies	10	172	2.87
Install 2 new needle assemblies	5	177	2.95
Replace 2 shroud plates	6	183	3.05
Install CIA into Combustion Chamber	24	207	3.45
Release then connect cooling loop coils to the CIA/IRR	3	210	3.50
Release then connect electrical connectors to CIA/IRR	3	213	3.55
Close Chamber Door	5	218	3.63
Translate and Fold Down Optics Bench	20	238	3.97
Unstow Removable Latch (RL)	15	253	4.22
Keep CIR IPP in UML #5	0	253	4.22
Keep CIR Illumination Package in UML #6	0	253	4.22
Attach RL to IPSU @ UML #3	2	255	4.25
Uninstall IPSU from UML #3	5	260	4.33
Detach RL from IPSU	2	262	4.37
Secure RL	1	263	4.38
Combine IPSU from UML #3 to IPSU @ UML # 7	5	268	4.47
Keep CIR LLL-UV (OH) at UML #8	0	268	4.47

Post DCE-2 Crew Time for Reconfiguration of CIR for BCDCE – Continued

TASK	CREW TIME (minutes)	CREW TIME ELAPSED (min)	CREW TIME ELAPSED (hrs)
Keep Common IPSU at UML #1	0	268	4.47
Retrieve RL	1	269	4.48
Attach RL to CIR HFR/HR at UML # 2	2	271	4.52
Uninstall CIR HFR/HR from UML #2 then secure	2	273	4.55
Unstow Modified HFR/HR Lens	15	288	4.80
Replace original HFR/HR Lens with Modified Lens	10	298	4.97
Stow Old HFR/HR Lens	10	308	5.13
Unsecure Modified HFR/HR	2	310	5.17
Install Modified HFR/HR into UML #2	5	315	5.25
Unstow MDCA PIV Camera	15	330	5.50
Detach RL from Modified HFR/HR at UML #2	2	332	5.53
Attach RL to MDCA PIV Camera	2	334	5.57
Install MDCA PIV Camera at UML #3	5	339	5.65
Detach RL from MDCA PIV Camera	2	341	5.68
Attach RL to CIR LLL-IR (CH) at UML #4	2	343	5.72
Uninstall CIR LLL-IR (CH) at UML #4	5	348	5.80
Detach RL from CIR LLL-IR (CH) and secure RL	2	350	5.83
Stow CIR LLL-IR (CH)	10	360	6.00
Unstow MDCA PIV Camera	15	375	6.25
Attach RL to MDCA PIV Camera	2	377	6.28

Post DCE-2 Crew Time for Reconfiguration of CIR for BCDCE – Continued

Total Estimated Crew Time Needed to Reconfigure CIR for BCDCE after the completion of DCE-2 so that BCDCE is ready to be executed.

TASK	CREW TIME (minutes)	CREW TIME ELAPSED (min)	CREW TIME ELAPSED (hrs)
Install MDCA PIV Camera at UML #4	5	382	6.37
Detach RL from MDCA PIV Camera	2	384	6.40
Stow RL	10	394	6.57
Fold Up and Translate Optics Bench	20	414	6.90
Unstow new Adsorber Cartridge	15	429	7.15
Install new Adsorber Cartridge	15	444	7.40
Unstow 1 new 2.25L O2 Bottle	15	459	7.65
Install 1 new 2.25L O2 Bottle	2	461	7.68
Close Rack Doors and Secure	10	471	7.85
TOTAL	**471**	**471**	**7.85**

FCF/MDCA Crew Operations Requirements

ARIS Installation and setup (1 time event)	6 hours
FCF Rack post launch configuration (1 time event)	3 hours
CIR Verification equipment installation (1 time event) *(includes on orbit assembly of any diagnostics or equipment)*	3.5 hours
Crew Time Needed for Cleanup and Stowage Post Verification (1 time event)	3 hours
Rack Configuration for DCE-2 (1 time event)	7.4 hours
Crew Operations during DCE-2	21.6 hours
Reconfiguration of CIR for BCDCE (1 time event)	7.8 hours
Total Crew time required from initial CIR Configuration through DCE-2 operations to and including the Setup and Configuration of BCDCE (Crew time needed during BCDCE runs or later not included)	**52.3 hours**

UF3 CIR Stowage and Up Mass-Post Launch Installable Hardware and Components

Assembly	Quantity	Control Mass (Kg) 1 Unit	Stowage Volume (m3) 1 Unit	Total Control Mass (Kg)	Total Stowage Volume (m3)
Diagnostics-Color Camera (Includes DCM)	1	12.600	0.032	12.600	0.032
Diagnostics- LLL UV Camera (Includes DCM)	1	15.000	0.032	15.000	0.032
Diagnostics-HiBMs Camera (Includes DCM)	1	12.000	0.032	12.000	0.032
Diagnostics-LLL IR Camera (Includes DCM)	1	15.600	0.032	15.600	0.032
Diagnostics-Mid-IR Camera (Includes DCM)	1	13.200	0.032	13.200	0.032
Diagnostics-HFR/HR Camera (Includes DCM)	1	11.500	0.032	11.500	0.032
Diagnostics-Illumination Package (Includes ICM)	1	11.800	0.025	11.800	0.025
Diagnostics-IPP	1	19.200	0.053	19.200	0.053
Diagnostics-IPSU's	2	8.000	0.012	16.000	0.024
Diagnostics-Removable Latch	1	2.600	0.008	2.600	0.008
FOMA-FCU	1	15.000	0.004	15.000	0.004
FOMA-Gas Chromatograph Additional On-Orbit Mass	1	13.100	0.002	13.100	0.002
FOMA-Bottle (3.8L)	0	10.500	0.009	0.000	0.000
IOP-I/O Processor Harddrives	2	4.600	0.024	9.200	0.048
ARIS-Additional On-Orbit Mass	1	14.500	0.001	14.500	0.001
Rack-to-Station I/F Umilical Set	1	10.700	0.001	10.700	0.001
Station Support Computer (SSC) Laptop	1	3.500	0.001	3.500	0.001
Verification Insert	1	40.000	0.080	40.000	0.080
TOTAL				**235.500**	**0.439**

UF3 MDCA Stowage and Up Mass-Post Launch Installable Hardware and Components

Assembly	Quantity	Control Mass (Kg) 1 Unit	Stowage Volume (m3) 1 Unit	Total Control Mass (Kg)	Total Stowage Volume (m3)
Diagnostics-MDCA PIV Camera (Includes ICM)	2	10.700	0.013	21.400	0.026
Diagnostics-PI Provided Illumination	1	9.600	0.025	9.600	0.025
Diagnostics-PI Specific Electronics	1	19.800	0.022	19.800	0.022
FOMA-Bottle (2.25L)	2	6.700	0.006	13.400	0.012
FOMA-Bottle (1L)	7	4.000	0.004	28.000	0.028
FOMA-Adsorber Cartridge	2	4.900	0.003	9.800	0.006
Chamber Insert Assembly	1	45.700	0.080	45.700	0.080
Fuel Resevoir Assemblies (Include Syringes)	17	0.772	0.001	13.117	0.018
Deployment Needle Assemblies	10	0.039	0.000	0.390	0.001
Ingnitor Tip Assemblies	6	0.000	0.000	0.002	0.000
Retractable Indexing Fiber Assemblies	13	0.982	0.031	12.766	0.400
TOTAL				**173.975**	**0.618**

<u>Total UF3 Stowage and Up Mass for CIR and MDCA:</u>

CIR=235.5 Kg; .44 m3

MDCA=173.98 Kg; .62 m3

TOTAL UF3= 409.5 Kg; 1.06 m3 (1.38 m3 with 30% stowage factor)

CIR/MDCA On-orbit Estimated Stowage Requirements

(Rack Configured for DCE-2)

Stowed Item	# of Stowed Items	Single Unit Volume	Total Volume (m3)
Diagnostics-Color Camera (CIR)	1	0.032 m3	0.032
Diagnostic-HiBMs (CIR)	1	0.032 m3	0.032
Diagnostic-Mid-IR (CIR)	1	0.032 m3	0.032
Removable Latch (CIR)	1	0.008 m3	0.008
Diagnostic-CIR Illumination (CIR)	1	0.025 m3	0.025
Verification CIA	1	0.08 m3	.08
Subtotal CIR			0.207 m3
Diagnostic-MDCA PIV Camera (MDCA)	1	0.013 m3	0.013
FOMA-Bottle 2.25L (MDCA)	6	0.006 m3	0.036
FOMA-Bottle 1 Liter (MDCA)	1	0.004 m3	0.04
Adsorber Cartridge (MDCA)	1	0.006 m3	0.006
Fuel Reservoirs/w syringes (MDCA)	15	0.001 m3	0.016
Needles (MDCA)	10	0.000 m3	0.001
Ignitor Tips (MDCA)	6	0.000 m3	0.001
Retractable Indexing Fibers (MDCA)	13	0.0308 m3	.4004
MDCA Subtotal			**.5134**
Total Stowed Volume (with stowage factor)			**.94 m3**

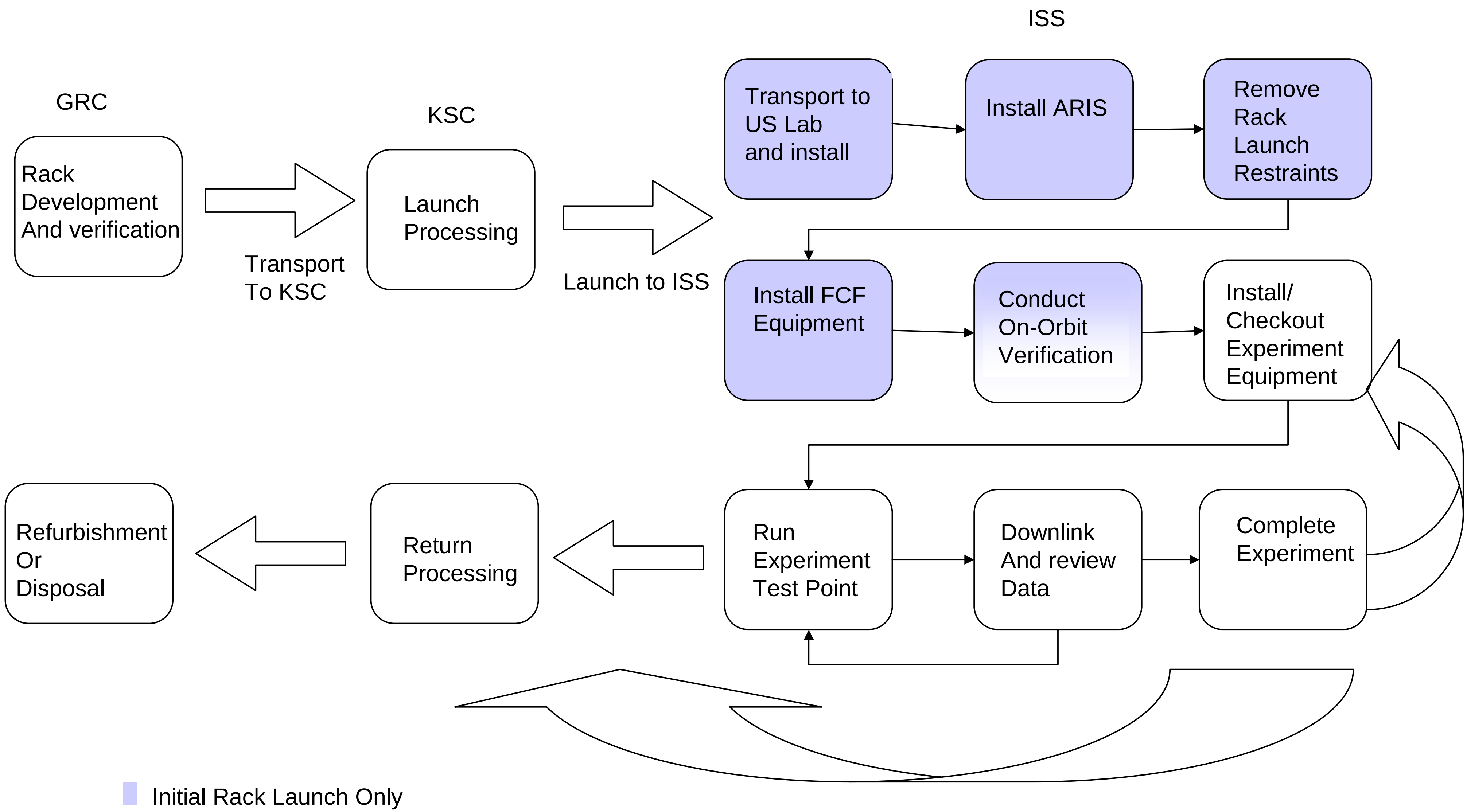
MDCA Resource Summary

Experiment Number	On-Orbit Mass (kg)	Peak (Watts)	Average (Watts)	Total Energy (kW-h)	Crew Time (mins)	GN_2 (liters)	Data (Mb)	Time (hrs)	Stowage (m^3)	Upmass (kg)
C6 - DCE II	1021.5	2070.0	648.5	442.7	808	1201.4	1.39E+06	513.79	0.2161	131.2
C6 - BCDCE	1021.5	2168.3	623.6	466.4	636	330.6	1486.9	563.90	0.5130	151.9

FIR Operations Overview

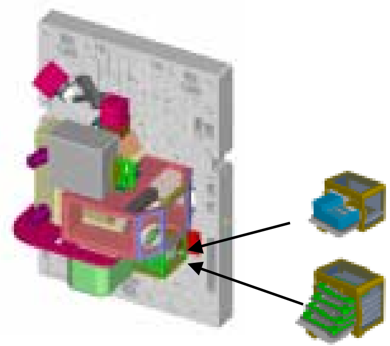
- ARIS and FCF Rack configuration operations are assumed to be identical to CIR (see previous slides)
- On-Orbit Verification needs more definition
- Still working to better define FIR/LMM resource requirements

Generic FCF Rack Operations Concept Flow



FIR Generic Operational Flow

Configuration of FIR
- Install PI Package
- Configure Avionics Package (s)
- Install Diagnostics
- Install Test Samples

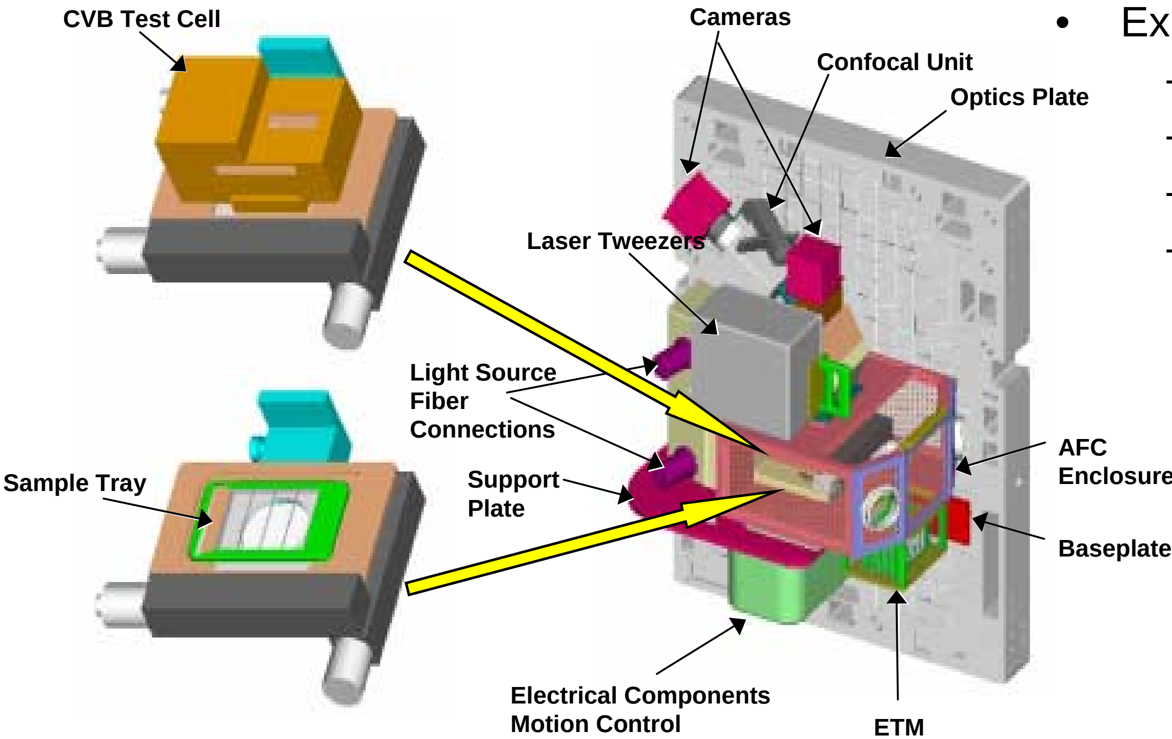


Pre-Run
- Power up to minimal power mode
- Uplink Test Procedures
- Power on Avionics
- Transfer Test Procedures to Avionics
- Review Health and Status

Test Operations
- Power on Diagnostics
- Review Health and Status
- Start Test Run – Perform Real-Time Test Procedures
- Downlink Real-Time Data
- Shut-down Diagnostics

Post Run
- Post Process Data
- Transfer Data to IOP
- Power down to Minimal Power Mode
- Downlink/Archive Data (Uplink Procedures)

LMM Overview



LMM Experiment Flow

- Example Colloid Experiment Run General Flow
  - Power On FIR avionics
  - Upload command procedures
  - Run any health and status checks
  - Power on diagnostics for sample homogenization
    - Run any diagnostic health and status checks
    - Homogenize samples and record data
    - Monitor progress with real-time data captures
    - Power down diagnostics
    - Downlink data for review
  - Continue science with other samples
  - During other daily science operations record crystallization process and downlink data as necessary
  - After 3 months, use samples in rheology, local melting, zone refining, and forced pattern experiments

CVB: Estimated Crew Time (1 of 2)

TASK	CREW TIME (min)	CREW TIME ELAPSED (min)	TOTAL CREW TIME (hrs)
Initial LMM/CVB set-up*	1440	1440	24.00
Install CVB 1st ETM Containing 1st Platen			
Unstow ETM #1	45	1485	24.75
Open Rack Doors	10	1495	24.92
Rotate LMM Out	10	1505	25.08
Attach ETM to AFC	10	1515	25.25
Remove Glove Plugs	10	1525	25.42
Insert 1st Platen	10	1535	25.58
Insert Glove Plugs	10	1545	25.75
Rotate LMM In	10	1555	25.92
Close Rack Doors	10	1565	26.08

*One-Time Operation

CVB: Estimated Crew Time (2 of 2)

TASK	CREW TIME (min)	CREW TIME ELAPSED (min)	TOTAL CREW TIME (hrs)
Platen Changes			
Open Rack Doors	10	1575	26.25
Rotate LMM Out	10	1585	26.42
Remove Glove Plugs	10	1595	26.58
Demount Platen and Place in ETM	10	1605	26.75
Remove ETM from AFC	10	1615	26.92
Stow ETM	45	1660	27.67
Attach New ETM to AFC	10	1670	27.83
Insert New Platen	10	1680	28.00
Insert Glove Plugs	10	1690	28.17
Rotate LMM In	10	1700	28.33
Close Rack Doors	10	1710	28.50
Repeat Platen Changes 3X			
Platen Change	145	2145	35.75
TOTAL (Hours)			**35.75**

PHaSE-2 and PCS-II: Estimated Crew Time (1 of 4)

TASK	CREW TIME (min)	CREW TIME ELAPSED (min)	CREW TIME ELAPSED (hrs)
Re-configure for PHaE-2, PCS-II (part a)*			
Open Rack Doors	10	10	0.17
Mount Condensor Assembly to the Microscope	40	50	0.83
Mount the Laser Tweezers to the Microscope	40	90	1.50
Mount the Laser Tweezers Electronic Box to the Optics Bench	30	120	2.00
Connect the Laser Tweezers to the Electronic Box	20	140	2.33
Remove LMM Monochrome Camera from the Tube Lens	20	160	2.67
Mount the Confocal Unit and LMM Monochrome Camera to the Microscope	40	200	3.33
Translate the Bench Out	10	210	3.50
Rotate the Bench Down for access to the Nd:YAG Laser	10	220	3.67
Connect the FIR Nd:YAG 532 to the Confocal Unit	15	235	3.92
Rotate the Bench Up	10	245	4.08
Translate the Bench In	10	255	4.25

*One-Time Operation

PHaSE-2 and PCS-II: Estimated Crew Time (2 of 4)

TASK	CREW TIME (min)	CREW TIME ELAPSED (min)	CREW TIME ELAPSED (hrs)
Mount the LMM Color Camera to the Microscope Tube Lens	20	275	4.58
Adjust the Color Surveillance Camera	20	295	4.92
Disconnect White Light from Epi-Illumination	10	305	5.08
Connect FIR White Light to LMM Trans-Illumination Port	10	315	5.25
Rotate LMM Out	10	325	5.42
Remove Glove Plugs	10	335	5.58
Remove CVB Platen #5	10	345	5.75
Move CVB Platen #5 into ETM #5	10	355	5.92
Stow CVB ETM #5	45	400	6.67
Unstow PHaSE-2/PCS-II ETM	15	415	6.92
AFC	10	425	7.08
Insert 1st Platen	10	435	7.25
Insert Glove Plugs	10	445	7.42
Rotate LMM In	10	455	7.58
Close Rack Doors	10	465	7.75

PHaSE-2 and PCS-II: Estimated Crew Time (3 of 4)

TASK	CREW TIME (min)	CREW TIME ELAPSED (min)	CREW TIME ELAPSED (hrs)
Platen Changes			
Open Rack Doors	10	475	7.92
Rotate LMM Out	10	485	8.08
Remove Glove Plugs	10	495	8.25
Swap Platens	20	515	8.58
Insert Glove Plugs	10	525	8.75
Rotate LMM In	10	535	8.92
Close Rack Doors	10	545	9.08
Repeat Platen Changes 40X			
Platten Change	80	3745	62.42
Change-over from Laser Tweezers to Spectrometer for PCS-II, part b (completed with platen change)*			
Remove Laser Tweezers from Flourescence Filter	90	3835	63.92
Connect Spectrophotometer to Florescence Filter	90	3925	65.42

*One-Time Operation

PHaSE-2 and PCS-II: Estimated Crew Time (4 of 4)

TASK	CREW TIME (min)	CREW TIME ELAPSED (min)	CREW TIME ELAPSED (hrs)
Swap-Out of IOP Hard Drives**			
Open IOP - Swap Drives	10	TBD	65.42+TBD
TOTAL (Hours)			**65.42+TBD**

**Coordinated with Platen Changes

LΦCA: Estimated Crew Time (1 of 3)

TASK	CREW TIME (min)	CREW TIME ELAPSED (min)	CREW TIME ELAPSED (Hrs)
Install LΦCA ETM, 1st Platen			
Open Rack Doors	10	10	0.17
Rotate LMM Out	10	20	0.33
Remove Glove Plugs	10	30	0.50
Remove PCS-II Platen	10	40	0.67
Remove PHaSE-2/PCS-2 ETM	10	50	0.83
Stow PHASE-2/PCS-2 ETM	45	95	1.58
Unstow LΦCA ETM	15	110	1.83
Attach LΦCA ETM to AFC	10	120	2.00
Insert 1st Platen	10	130	2.17
Insert Glove Plugs	10	140	2.33
Rotate LMM In	10	150	2.50
Close Rack Doors	10	160	2.67

LΦCA: Estimated Crew Time (2 of 3)

TASK	CREW TIME (min)	CREW TIME ELAPSED (min)	CREW TIME ELAPSED (Hrs)
Platen Changes and IOP HD Swap			
Open Rack Doors	10	170	2.83
Rotate LMM Out	10	180	3.00
Remove Glove Plugs	10	190	3.17
Remove Platten	10	200	3.33
Insert Glove Plugs	10	210	3.50
Remove LΦCA ETM	10	220	3.67
Fix Platten from ETM in Glovebox	TBD		
Insert LΦCA ETM	10	230	3.83
Remove Glove Plugs	10	240	4.00
Swap Platens	20	260	4.33
Insert Glove Plugs	10	270	4.50
Rotate LMM In	10	280	4.67
Swap IOP HDs	10	290	4.83
Close Rack Doors	10	300	5.00
Repeat Platen Changes and IOP HD Swaps 4X			
Platen Changes / HD Swap	140	860	14.33

LΦCA: Estimated Crew Time (3 of 3)

TASK	CREW TIME (min)	CREW TIME ELAPSED (min)	CREW TIME ELAPSED (Hrs)
Secure and Stow LMM*	720	1580	26.33
TOTAL (Hours) TBDs not Included			**26.33+TBDs**

*One-Time Operation

UF-5 Launch Mass and Stowage

Assembly	Quantity	Stowage Volume (cm^3)	Mass (Kg)	Total Volume (m^3)	Total Mass (Kg)
DCMs	4	4341	3.3	0.017	13.2
Color Analog Controller	1	3174	1.5	0.003	1.5
Color Analog Camera Head	1	48		0.000	
Monochrome Digital IAM	2	1515	0.9	0.003	1.82
UHFR Camera	1	1674	2.0	0.002	2
Color Macro OM	1	1429	1.5	0.001	1.47
Monochrome Macro OM	2	3089	1.3	0.006	2.6
High Magnification OM	1	5593	1.8	0.006	1.81
White Light Panel (with bundle)	1	9391	2.4	0.009	2.41
25mm Collimator	1	270	0.2	0.000	0.2
50mm Collimator	1	917	0.8	0.001	0.8
Gimbaled Mirror	1	4508	4.7	0.005	4.66
Translation Stage	1	1980	5.2	0.002	5.17
Movable Mount	2	6415	4.2	0.013	8.38
SAMS FF Head	1	386	1.2	0.000	1.2
LMM - Launch Hardware	1	350000	263.0	0.325	263
Total				**0.512** (Including 30% Packaging Factor)	**310.22**

FIR/LMM On-orbit Estimated Stowage Requirements

(Rack Configured for CVB)

Stowed Item	# of Stowed Items	Single Unit Volume (m^3)	Total Volume (m^3)
DCMs	4	0.0043	0.017
Monochrome Digital IAM	2	0.0015	0.003
Monochrome Macro OM	2	0.003	0.006
High Magnification OM	1	0.006	0.006
White Light Panel	1	0.009	0.009
25mm Collimator	1	0.001	0.001
50mm Collimator	1	0.001	0.001
Gimbaled Mirror	1	0.005	0.005
Translation Stage	1	0.002	0.002
Moveable Mount	2	0.006	0.012
PI FSAP (Verification Unit)	1	0.0124	0.012
FIR Subtotal			**0.074**
CVB ETMs	4	0.009	0.036
LMM Subtotal			**0.036**
Total Stowed Volume (w/ 30% Stowage Factor)			**0.148**

FCF/FIR Crew Operations Requirements

ARIS Installation and Setup	6hrs
FCF Rack Post Launch Configuration	3hrs
FIR Verification Equipment Installation	TBD
Reconfigure for LMM/CVB and crew Operations	35.8hrs
Reconfigure for Phase-II/PCS-2 and Crew Operations	65.4hrs+TBD (HD Swaps)
Reconfigure for LΦCA	26.3hrs
Total Crew Time Required for Operations	**136.5hrs+TBD**

FIR Resource Summary

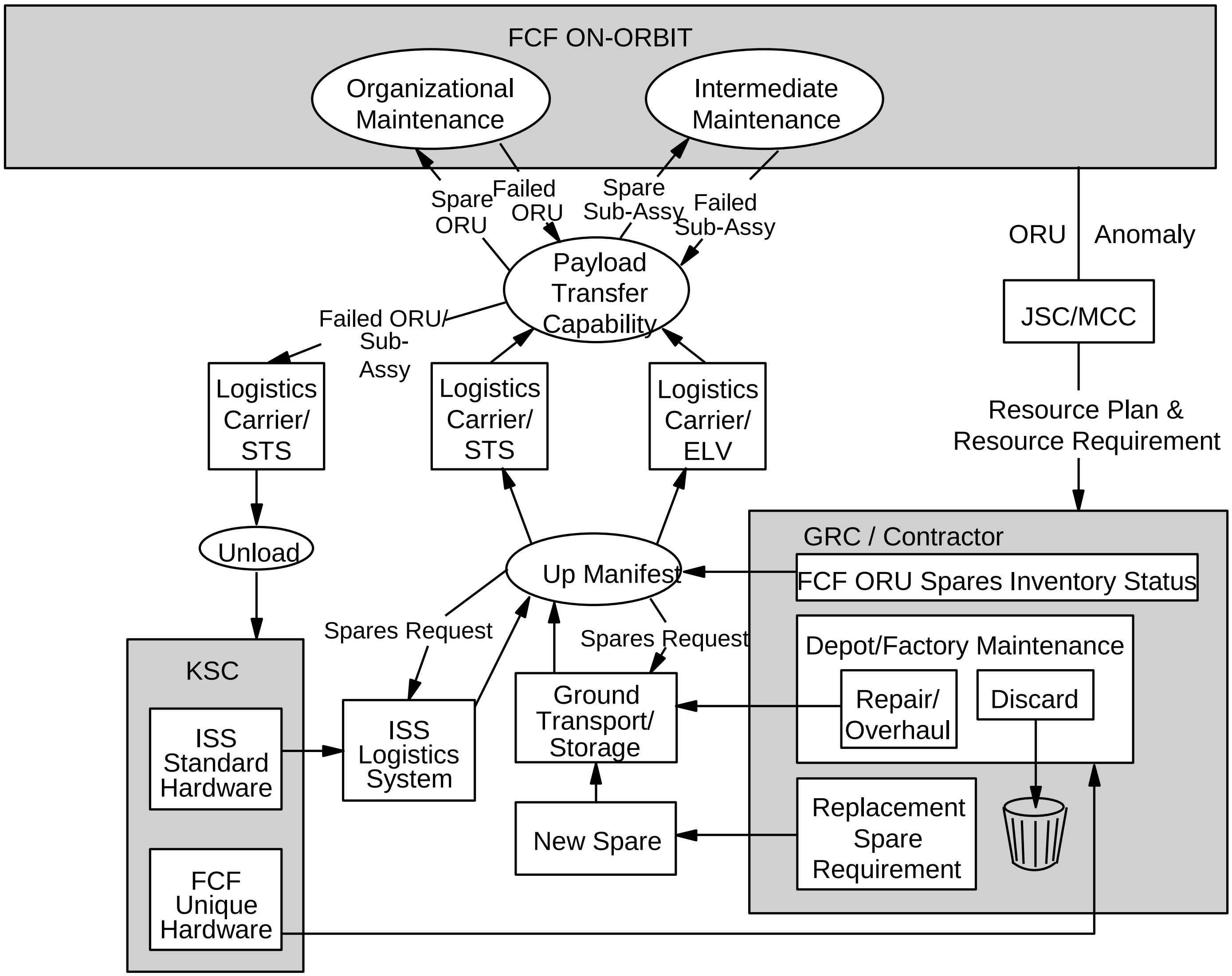
		Power				Downlink			
Experiment	On-Orbit Mass (kg)	Peak (Watts)	Average (Watts)	Total Energy (kW-hrs)	Crew Time (mins)	Data (GB)	Time (hrs)	Stowage (m^3)	Upmass (kg)
CVB	752.7	1189	1090	950	2145	13	8.2	0.33	264
PHaSE-2 / PCS-2	752.7	1244	1100	3443+TBD	3925+TBD	TBD	TBD	0.33	106
LΦCA	752.7	1244	1028	1312	1580+TBD	440	278	0.33	53

Logistics

Logistics

- Integrated Logistics Support Plan developed
  - Outlines the approach the FCF Project will take to define the overall support concept for the FCF System
  - Contains sections on LSA, Maintenance, PHS&T, and Support Equipment
  - Provides information on ORU and intermediate level maintenance determination
- Support equipment being identified
  - Production equipment needed for post deployment support will be identified
- Tools for determining optimum spares, LCC, LSAR data management being selected

FCF Logistics and Maintenance Concept



Reliability Methodology and Status

Methodology

- Subsystems have been identified from the CIR and FIR racks.
- Individual Reliability Prediction Analyses will be performed on each major subsystem down to the COTS/component level. Intent is to drive improvement in subsystem's "inherent reliability."
- FMEA/CIL Analyses will be performed on each major subsystem down to the ORU/component level. Intent is to identify and mitigate all "safety critical" and "mission critical" failure modes.
- CIR and FIR Limited Life Items Lists will be driven from the above analyses.
- Reliability Summary Reports will be created to meet criteria found within FCF-PLN-0045 (FCF Reliability/Maintainability Plan).

Reliability Methodology and Status

Status

- 2 Reliability Prediction Analyses are complete. 6 additional major subsystem's Analyses are 75% complete. Balance are approximately 25% complete. Working with subsystem design leads to obtain required information for completion of pending analyses.
- Functional level FMEA/CIL's were completed for initial PDR submission. Detailed work is underway on 4 subsystems down to the ORU/component level, including failure modes driven from radiation effects. Additional subsystems will follow.
- Preliminary top level Limited Life Items Lists have been released. Final comprehensive Limited Life Items List's pending completion of Reliability Prediction Analyses and FMEA/CIL Analyses.
- Preliminary Reliability Summary Reports have been released. Final documents pending completion of Reliability Prediction Analyses and FMEA/CIL Analyses.

Maintenance

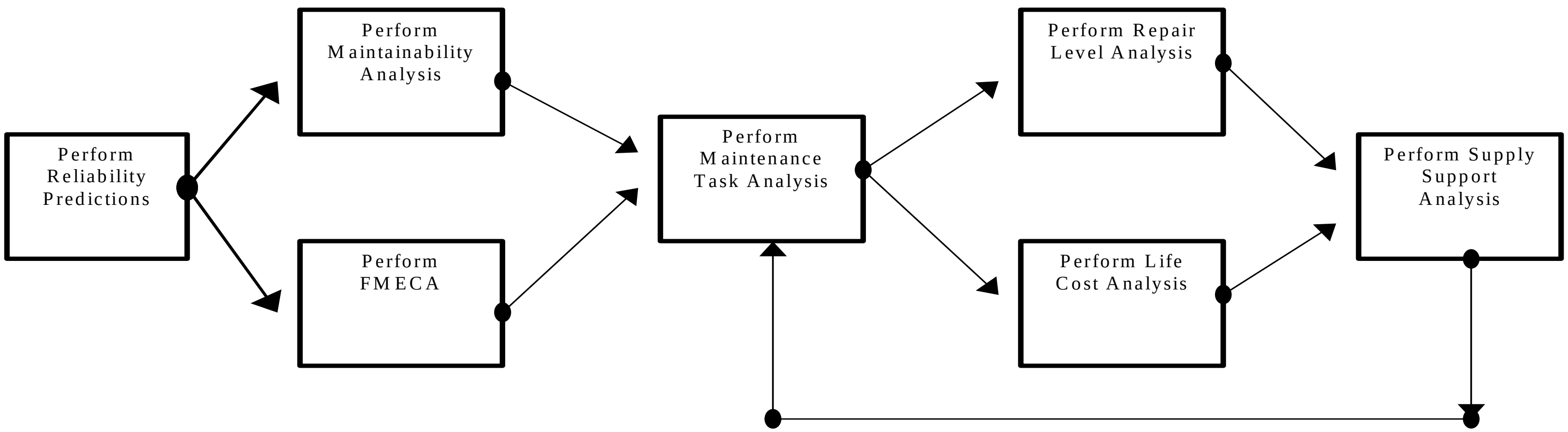
- ORUs are defined by the following methods:
  - An item which can be removed and replaced at the organizational (on-orbit) level of maintenance.
  - A hardware element having a probability of no failure (reliability) of less than 90%.
- The FCF has defined the following 3 levels of maintenance:
  - Organizational: Represents ORU changeout on orbit.
  - Intermediate: Repair of an ORU on orbit (card level changeout).
  - Depot: Repair of an item at GRC or vendor site.
- The primary on-orbit maintenance concept is to do ORU replacement.
- In some cases it may make sense to provide the capability to repair an ORU on orbit (intermediate level) in order to return the FCF to service.
  - Limits on stowage and upmass are the drivers.
  - Must be weighed against increases in crew time (MTTR).
  - Ability to failure detect to that level.
- Maintenance activities will cover both corrective and preventive maintenance.

Spares Provisioning Methodology

- During the design and development process of the FCF, the supply function will use reliability data and failure prediction methods to determine the recommended number of spares and the maintenance locations to ensure that FCF meets the following ground-rules and constraints:
  - FCF mission Operational Availability requirement of 83% over 10 years
  - 4 logistics flights per year
  - Annual transportation up-mass allocations of 150 kg
  - On-orbit volume stowage allocation of 40% rack equivalent volume ~0.40 m^3
- Provisioning is an iterative process that identifies types and quantities of spares, repair parts and consumables for flight hardware and support equipment which are procured to sustain a system for a specified period of time. The provisioning program is a tailored approach to reduce the amount of cost to the customer and still maintain the performance characteristics of the FCF system.

Spare Provisioning Methodology

FLUIDS & COMBUSTION FACILITY – SPARES PROVISIONING WORK FLOW



After reliability data and failure prediction data is available the LSA process begins. Provisioning analysis is a subset of LSA.

LOGISTICS SUPPORT ANALYSIS IS AN ITERATIVE PROCESS UNTIL OPTIMUM AVAILABILITY IS ACHIEVED IN THE MOST COST EFFECTIVE MANNER

Spares Provisioning Methodology

- The figure on the previous slide illustrates the data input and output stream that becomes the iterative process for the FCF spares provisioning function.
- Identification of spare candidates and quantities are based upon the following input criteria:
  - Hardware and functional criticality
  - Procurement lead time, availability, unit price and minimum buy
  - Reliability, maintainability and maintenance analysis data
  - NHA hardware quantities
  - Repair TAT and condemnation rates
  - Limited life and shelf life items
  - Technological advances and obsolescence
  - Repair vs. discard analysis

Preliminary On-Orbit Spares List

ORU	SYSTEM	VOLUME EACH (m^3)	VOLUME TOTAL (m^3)
FCU	CIR	0.026	0.026
COLOR CAMERA	CIR	0.032	0.032
LLL-UV CAMERA	CIR	0.032	0.032
HiBMs CAMERA	CIR	0.032	0.032
LLL-IR CAMERA	CIR	0.032	0.032
MID-IR CAMERA	CIR	0.032	0.032
ILLUMINATION PACKAGE	CIR	0.025	0.025
IPP	CIR	0.053	0.053
HFR/HR CAMERA	CIR/FIR	0.032	0.032
EPCU	COMMON	0.041	0.041
IOP	COMMON	0.0422	0.0422
DCM	COMMON	0.0023	0.0046
COMMON IPSU	COMMON	0.0151	0.0151
ATCU FAN	COMMON	0.0145	0.0145
EEU	COMMON	0.0452	0.0452
COLOR CAMERA	FIR	0.002	0.002
COLOR CAMERA IAM	FIR	0.003	0.003
HR IAM PACKAGE	FIR	0.003	0.003
COLLIMATOR ASSY. 10MM	FIR	0.006	0.006
COLLIMATOR ASSY. 25MM	FIR	0.006	0.006
COLOR LENS ASSY.	FIR	0.005	0.005
FSAP	FIR/SAR	0.0276	0.0276
Total with Stowage factor			0.66

Initial Preventive Maintenance Task list

System	Preventive Maintenance Task Description	Number of Components	Task Frequency	Task Completion Time	Total Task Completion Time
ATCU					
	Clean Heat Exchanger EMI Screen	1	YEARLY	TBD	TBD
	R&R Lint Filter	2	YEARLY	1.00 HRS.	2.00 HRS.
WTCU					
	Visual Inspection for Water Leaks	1 RACK	ON EACH POWER UP	0.5 HRS.	0.5 HRS.
Combustion Chamber					
	Calibrate Pressure Transducers	4	YEARLY	TBD	TBD
	Check Pressure Switches to verify set points	3	YEARLY	TBD	TBD
	Replace Temperature Probes	4	TBD	TBD	TBD
FOMA					
	Calibrate Pressure Transducers	30	YEARLY	TBD	TBD
	Calibrate Gas Mass Flow Rate Controllers	4	YEARLY	TBD	TBD
	R&R Dew Point Sensor	1	YEARLY	5.00 HRS.	5.00 HRS
	R&R Oxygen Sensor	1	YEARLY	5.00 HRS	5.00 HRS

FCF Use of the TSC

Telescience Support Center (TSC) Provides

Space and resources for science teams

- Hardware interfaces
- Training and simulations

Facilities - 24 x 7 support for:

- Network
- Data
- Video
- Audio

IT Services

- Science Data Distribution
- Data Archival (and playback)
- Data recording (Video)
- reconfiguration
- Remote site setup and support

TSC

- During real-time operations, the FCF operations team will control the on-orbit hardware using TSC provided data systems and hardware.
  – Health and Status data as well as engineering data will be displayed using GUIs developed for the TSC platforms.
  – High rate image data will be stored upon receipt and made available over FCF or PI provided equipment interfacing with the TSC networks.
  – PI commanding of FCF hardware will be negotiated subject to FCF retaining final authority for commanding of FCF systems.
  – The PI operations team at the TSC will utilize TReK workstations for telemetry, commanding, and mission services. The PI team will supply GSE for image analysis and science data processing and storage. Access to the FCF image data storage facility will be required.
- Prior to each mission, the FCF and PI operations teams will participate in mission simulations with MSFC and JSC.

Required Capabilities

- Audio Communications
- Teleconferencing and Video Conferencing
- Telemetry Processing and Recording
- Video receipt, distribution and recording
- High rate data receipt and recording
- Access to PIMS
- Display Building Tools
- Training
- Command generation, processing and management
- Remote site extension of selected services
- Support for Fluids and Combustion experiments operating during the same increment

Roles and Responsibilities

FCF Responsibilities

- FCF System display building
- Train PI teams on FCF operations
- Participate in replanning activities
- Manage FCF data
- Control access to commanding
- Provide status of FCF systems
- Ensure system readiness

PI Team responsibilities

- Develop hardware displays
- Train FCF on PI hardware operations
- Participate in replanning activities
- Provide status of PI hardware
- Ensure readiness for operations
- Provide hardware not provided by TSC

Real-Time Operations Staff Definition

- **FCF Ops Lead**
  - Responsible for the overall execution of the FCF daily plan
  - Point of contact with the Payload Operations D
  - Approves all Change Requests coming from either operations team
- **FCF Systems Engineer**
  - Responsible for monitoring the overall health and status of FCF subsystems
  - Coordinates anomaly resolution with appropriate personnel
- **FCF Data/Telemetry**
  - Responsible for maintaining cognizance of data that has been downlinked
  - Coordinates with the PI team Data/Telemetry to ensure data is received by PI teams before flight unit hard drives are overwritten
  - Coordinates with the the POIC for AOS/LOS and other on-orbit data system status
- **FCF Commanding**
  - Responsible for building and issuing commands to the FCF subsystems
  - Coordinates with the PI team to ensure proper sequencing and routing of commands
  - Coordinates with POIC commanding
- **FCF Procedure Engineer**
  - Responsible for clarifying any procedures for the crew
  - Coordinates with PODF Support and the POIC

Real-Time Ops Staff Service Requirements

	Voice Loops	PIMS	Commanding	ISS Video	Telemetry	Stored Data access	FCF High Resolution Image Display	FCF High Resolution Image Processing	Engineering Data Display	Trend analysis tools
Operations Lead	Yes	Yes	No	Yes	Yes	No	No	No	Yes	No
System Engineer	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Data	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Command	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	No
Procedures	Yes	Yes	No	Yes	Yes	No	No	No	Yes	No
Support Engineering	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FCF Increment manager	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No
FCF Science manager	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No

PI Team Staffing

- **PI or Project Scientist**
  - Responsible for all science issues related to the experiment
  - Monitors experiment progress and request and concur on all changes (OCR's, etc.)
- **PI Hdwr Ops Lead**
  - Responsible for the overall execution of the PI Hdwr daily plan
  - He/she interacts with the FCF Ops Lead, the PI or Project Scientist and the rest of the PI Hdwr team
  - Approves all Operational Change Requests coming from the PI Hdwr operations team
- **PI Hdwr Systems Engineer**
  - Responsible for monitoring the overall health and status of PI Hdwr subsystems and the status of consumable resources
  - Coordinates anomaly resolution with appropriate personnel
- **PI Hdwr Data/Telemetry**
  - Responsible for maintaining cognizance of data that has been downlinked from the flight unit
  - Coordinates with the FCF Data/Telemetry to ensure data is received by PI teams before flight unit hard drives are overwritten
- **PI Hdwr Commanding**
  - Responsible for building and issuing commands to the PI Hdwr subsystems
  - Coordinates with the FCF commanding to ensure proper sequencing and routing of commands
- **PI Hdwr Re-plan Engineer**
  - Responsible for clarifying any procedures for the crew
  - Coordinates with the FCF Procedure Engineer

PI Team Capabilities

	Voice Loops	PIMS	Commanding	ISS Video	Telemetry	Stored Data access	FCF High Resolution Image Display	FCF High Resolution Image Processing	Science Data Display	Trend analysis tools
PI or Project Scientist	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No
PI Hdwr Ops Lead	Yes	Yes	No	Yes	Yes	Yes	No	No	Yes	Yes
PI Hdwr Systems Engineer	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes
PI Hdwr Data/Telemetry	Yes	Yes	No	Yes	Yes	No	No	No	Yes	No
PI Hdwr Commanding	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	No
PI Hdwr Replan Engineer	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

FCF/TSC System Concept